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**Method for refilling brake circuits after a large consumption of compressed air and device for carrying out said method**

The invention relates to a method according to the preamble of claim 1 for refilling brake circuits after rapid compressed air consumption as well as to a device for performing the method.

There are known multi-circuit protective valves that divide the energy supply into several mutually independent load circuits and that, in the event of failure of a circuit, for example by line rupture, maintain a minimum pressure in the intact circuits. If a defect allowing more air to be lost than can be refilled by the compressor occurs in a service-brake circuit, the pressure in the service-brake circuits drops mutually until the closing pressure of the valve is reached. The pressure in the defective circuit continues to drop, whereas the closing pressure is maintained in the intact circuit. While the pressure in the defective circuit continues to drop, the circuit that is still intact can be refilled by the compressor until the opening pressure of the defective circuit is reached. There is established a dynamic equilibrium, in which the delivered compressed air can supply the circuits that are still intact (as well as secondary load circuits), although at the same time air is being lost via the defect. A disadvantage is that refilling by the compressor needs a relatively long time, since the compressor has only a relatively small delivery capacity, namely only 200 to 400 liters per minute as a

rule. Accordingly, the nominal energy in the brake system is restored only slowly, thus representing a disadvantage for system safety.

The object of the present invention is to provide a method and a device for performing the method, whereby the air pressure in the brake circuits can be restored very rapidly after rapid compressed air consumption.

This object is achieved by the invention according to claim 1. A device for performing the method is specified in claim 5.

Advantageous and expedient improvements of the invention are specified in the dependent claims.

The invention proposes to fill the brake circuits, after rapid air consumption, from a high-pressure load circuit in addition to the compressor. Since a high-pressure circuit can usually deliver a much larger air flow per unit time (up to several thousand liter/min) than a compressor (approximately 200 to 400 liter/min), the intact brake circuits are refilled very much faster than merely by means of the compressor. Thereby the nominal energy in the brake system, possibly reduced by a defective circuit, can be restored in a very short time. This is particularly important after a circuit break. System safety is substantially improved by distributing the energy between the circuits. This is achieved according to the invention by providing, for the high-pressure circuit, an electrically actuatable valve that is closed in the de-energized normal state, preferably a solenoid valve (alternatively, it is also possible to use a pilot-controlled valve) and, for

the other load circuits, including the brake circuits, electrically actuatable valves that are open in the normal state, preferably solenoid valves. All solenoid valves are in communication with one another via a common distributor line. To fill the brake system, the solenoid valve of the high-pressure circuit merely has to be switched to open position, in order to allow compressed air to flow out of the high-pressure circuit, in which the pressure or the energy has been conserved, via the open solenoid valves into the intact brake circuits.

The invention will be explained in more detail hereinafter on the basis of the attached drawing, in which there is illustrated a practical example, wherein:

Fig. 1 shows a block diagram of an inventively designed device for refilling of brake circuits after rapid compressed air consumption, and

Fig. 2 shows a diagram of the pressure variations during an operation of refilling of the brake system.

In the drawing, compressed air lines are represented by solid lines and electrical lines by broken lines.

The drawing shows a compressed air system 2 with a compressed air supply part 4 and a consumer part 6. Compressed air supply part 4 comprises a compressor 7, a compressor control device 8 and an air-dryer part 10.

Consumer part 6 is provided with a compressed air distributor line 14, a plurality of electrically actuatable solenoid valves 16, 18, 20, 22, 24 with restoring springs and a plurality of load circuits 26, 28, 30, 32, 34, 36, 38 supplied with compressed air via the solenoid valves.

From compressor 7, a compressed air supply line 40 leads via a filter 42, an air dryer 44 and a check valve 46 to distributor line 14, from which there are branched off lines 48, 50, 52, 54, 56 leading to the solenoid valves. From the solenoid valves, compressed air lines 58, 60, 62, 64, 66 lead to the load circuits. Line 62 splits into lines 62' and 62'' leading to circuits 30 and 32, a check valve 68 also being disposed in line 62''. A pressure limiter 70 is disposed in supply line 52. Line 54, which leads to solenoid valve 22, branches off downstream from pressure limiter 70. Line 64 splits into lines 64' and 64'' leading to circuits 34 and 36.

Pressure sensors 72, 74, 76, 78, 80, 82 monitor the pressure in the load circuits and in distributor line 14, and transmit the respective pressure as a pressure signal to electronic control unit 84, which directly controls the solenoid valves.

As an alternative to the pressure, it is also possible to monitor other variables of state, such as air flow rate, air mass and energy, in the load circuits and in the connecting line.

Load circuits 26, 28 can be service-brake circuits. Load circuit 30 can be a trailer-brake circuit, in which case normally two lines, a supply line and a brake line,

lead to the trailer. Load circuit 32 can be a parking-brake circuit with spring accumulator. Load circuits 34 and 36 can be secondary load circuits, such as operator's cab suspension, door controller, etc., in other words, all components that have nothing to do with the brake circuits. Load circuit 38 can be a high-pressure circuit.

Service-brake circuits 26, 28 are provided with compressed air reservoirs 90, 92 in conformity with EU Directive 98/12. High-pressure circuit 38 is provided with a compressed air reservoir 39.

The inventive compressed air system makes it possible to dispense with compressed air reservoirs in circuits 30, 32, 34, 36. As an example, it is permissible to supply other consumers from the service-brake circuits (circuits 26 and 28), provided the braking function or braking action of service-brake circuits 26 and 28 is not impaired.

Via a line 40', compressor 7 is mechanically (pneumatically) controlled by compressor controller 8. Compressor controller 8 comprises a solenoid valve 94 of small nominal width that can be switched by electronic control unit 84. In the de-energized normal state it is vented, as illustrated, whereby compressor 7 is turned on. If compressor 7 is to be turned off, for example because all load circuits are filled with compressed air, control unit 84 changes over solenoid valve 94 so that the pressure-actuatable compressor is turned off via line 40'. If solenoid valve 94 is switched to de-energized condition, for example because a load circuit needs compressed air, solenoid valve 94 is again switched to the normal state illustrated in the drawing, whereby line

40' is vented and in this way compressor 7 is turned on.

Air-dryer part 10 comprises a solenoid valve 100 with small nominal width, whose inlet 102 is in communication with distributor line 14 and via whose outlet 104 there is pneumatically switched a shutoff valve 106, which is in communication with supply line 40 of compressor 7 and serves for venting of the air dryer.

When solenoid valve 100 is switched to passing condition, compressor 7 no longer discharges into the load circuits but instead discharges via valve 106 to the atmosphere. At the same time, dry air flows from distributor line 14 (out of reservoirs 90, 92 of the service-brake circuits) via solenoid valve 100, throttle 108 and a check valve 110 through air dryer 44 for regeneration of its desiccant and further via filter 42 and valve 106 to the atmosphere.

Reference numeral 112 denotes an overpressure valve.

Solenoid valves 16, 18, 20, 22, 24 are controlled by control unit 84, solenoid valves 16 to 22 of load circuits 26 to 34 being open in de-energized normal state, while solenoid valve 24 of high-pressure circuit 38 is closed in de-energized normal state. Pilot-controlled solenoid valves can also be used. The pressure in the circuits is directly monitored at the solenoid valves by pressure sensors 72, 74, 76, 78, 80.

If the pressure were to drop in a load circuit, for example in circuit 30 (trailer-brake circuit), the compressed air supply also takes place by the service-brake circuits

via the open solenoid valves, the pressure in secondary load circuits 30 to 36 being adjusted by pressure limiter 70 to a lower level, such as 8.5 bar, than the pressure level of, for example, 10.5 bar in service-brake circuits 26 and 28 (see hereinafter). High-pressure circuit 38 is normally shut off by solenoid valve 24, and therefore is not in communication with the other circuits. It has a higher pressure level, for example 12.5 bar.

In the inventive compressed air system, the pressures in all load circuits 26 to 38 are measured by means of pressure sensors 72 to 80, which transmit electrical pressure signals to electronic control device 84 for evaluation. The control device compares the measured pressure values with a lower threshold value, which corresponds to the pressure to be adjusted in the respective load circuit. If the pressure of the brake circuits drops below this threshold value due to rapid air consumption or to line rupture or break, the control device switches solenoid valve 24 of high-pressure circuit 38 to open position, so that the high-pressure circuit is in communication with brake circuits 26 and 28 via connecting line 14 and open solenoid valves 16 and 18 and the energy stored in the high-pressure circuit is directed into the intact brake circuits and in this way the intact brake circuits are refilled. At the same time, control device 84 shuts off the defective circuits, by switching their solenoid valves to closed position. At the same time, compressor 7 also delivers into the intact brake circuits.

Refilling takes place very rapidly, since the high-pressure circuit delivers a much larger air flow per unit time into the brake circuits (up to several thousand liter/min) than the compressor, which in the embodiments used has a delivery capacity

of approximately 200 to 400 l/min, as already mentioned hereinabove.

As soon as the control device senses that the pressures in the high-pressure circuit and the filled brake circuits have become equal or that the index pressure value has been reached in the brake circuits, it closes solenoid valve 24 once again to interrupt the communication with the brake circuits.

The inventive method ensures distribution of energy between the load circuits, whereby very safe operating conditions are obtained.

Fig. 2 shows the pressure variations during a brake-circuit failure due, for example, to line break of brake circuit 26 at instant 120, and during refilling of intact brake circuit 28 at instant 124. Along with the pressure drop in circuit 26 (curve 72), the pressure in brake circuit 28 (see curve 74), which is in pneumatic communication, and in connecting line 14 (not illustrated) also drops. The pressure drop in connecting line 14 has the consequence that solenoid valve 94, which turns on the compressor.[,?]? is actuated at instant 121. To resupply intact brake circuit 28 with air, solenoid valve 24 of high-pressure circuit 38 is switched to the open state at instant 124, and defective brake circuit 26 is closed practically at the same time by closing of solenoid valve 16, so that intact circuit 28 and if necessary pneumatically coupled circuits 30 and 36, which are also intact, can be rapidly resupplied with air. The pressure in these circuits 30 and 36 undergoes little change during the entire venting operation, since pressure limiter 70 ensures decoupling of the pressure sensors from distribution line 14 (see broken pressure curves 76, 78 in Fig. 2).

In Fig. 2, the closing of solenoid valve 16 is illustrated at an instant 123, which occurs very close in time before instant 124; this is explained in somewhat more detail hereinafter. With the opening of solenoid valve 24 of high-pressure circuit 38 and the closing of defective brake circuit 26 at instant 124, the pressure in brake circuit 28 rises very rapidly, until the pressures of the high-pressure circuit and the brake circuit become equal or until the index pressure of the brake circuit is reached. The pressure drop in the high-pressure circuit during this rapid resupply with air can be detected at pressure sensor 80 (see drop of pressure curve 80 of high-pressure circuit 38 at instant 124). After it has been resupplied with air, circuit 28 is shut off for a certain time by switching solenoid valve 18 to blocked state at instant 125. During this time, the high-pressure circuit is refilled via the compressor, which has been switched on since the actuation of solenoid valve 94 at instant 121. To complete this refilling operation (instant 126), the control signals for solenoid valves 94 and 24 are reset once again, meaning that solenoid valve 94 is electrically energized and solenoid valve 24 is switched to the closed normal state once again. Thereafter the control signal for brake circuit 28 is also reset (instant 127), meaning that solenoid valve 18 is switched to open normal state once again.

Reference numerals 122 and 123 denote two brief test blocking pulses with a duration of 0.2 sec, for example, transmitted to the control input of solenoid valve 16 before instant 124 of definitive blocking of defective circuit 26. Such test blocking pulses can be used for safe detection of the failure of a circuit (circuit 26 in this case). The test blocking pulse at instant 122 blocks solenoid valve 16 for the indicated time interval of 0.2 sec. As a consequence of this blockage, the pressure at pressure sensor

74 in unaffected brake circuit 28 rises momentarily, because pressure reservoir 92 can supply air to intact circuit 28 once again when venting is interrupted by defective circuit 26. As regards defective circuit 26, a faster pressure drop takes place at pressure sensor 72 during the time of the test blocking pulse, since repressurization by the intact circuits is interrupted. Since the pressure drops more rapidly only in circuit 26 during the test blocking pulse, the suspicion that this circuit is defective is strengthened. In order to be certain whether this conclusion is correct, this test can be repeated by turning off valve 16 several times in pulsed manner. In the practical example according to Fig. 2, this is done a second and last time at instant 123. The pressure again drops more rapidly in circuit 26. It is now definitively established that circuit 26 is the defective circuit. Thereafter (beginning at instant 124) it is kept permanently blocked.